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Thruster Imaging Analysis for Control of a Solar Concentrator

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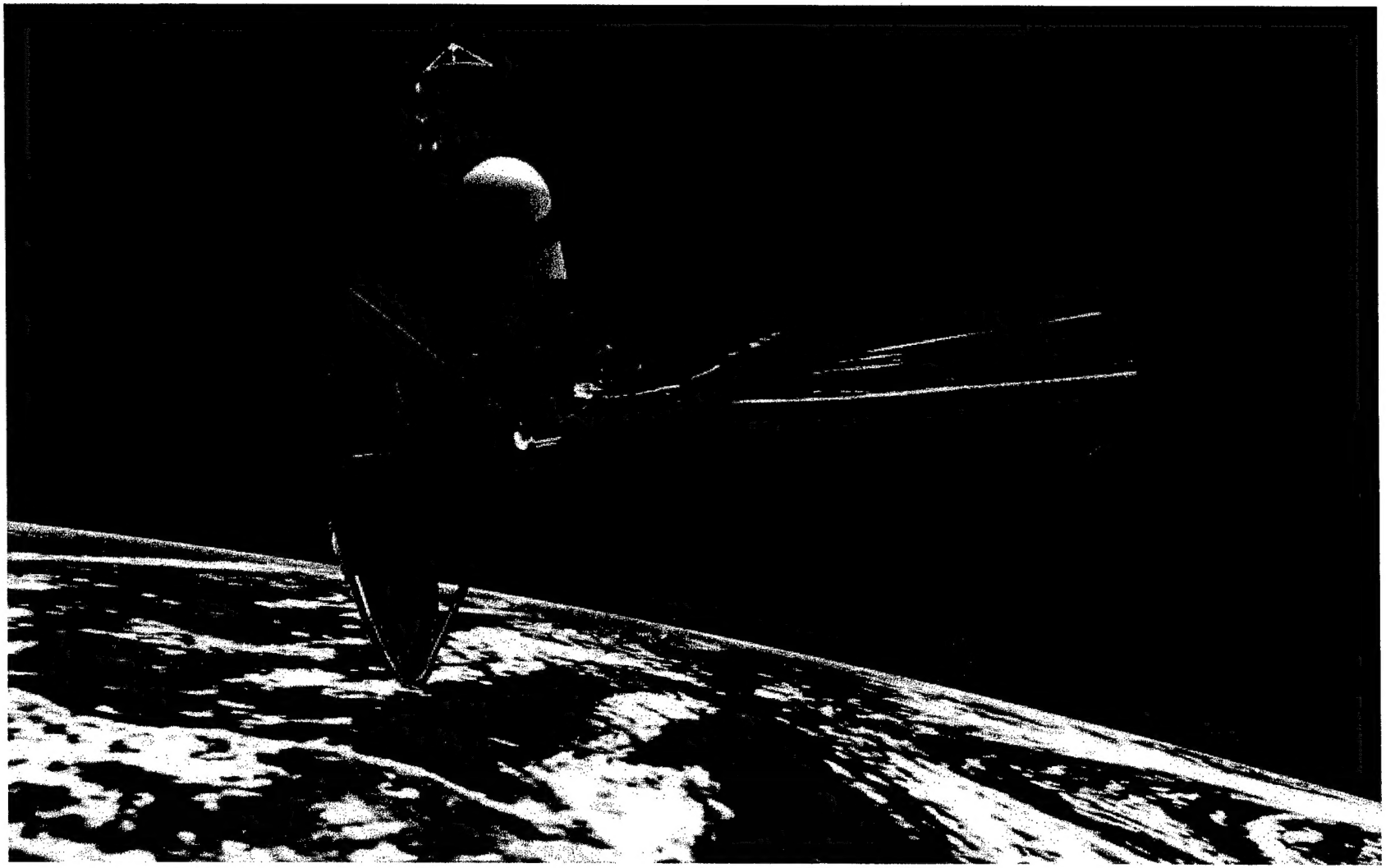
23 July 2003

Agenda

- Introduction
- Problem Definition
- Experimental Setup
- Results and Conclusion
- Future Work

Solar Thermal Spacecraft Configuration

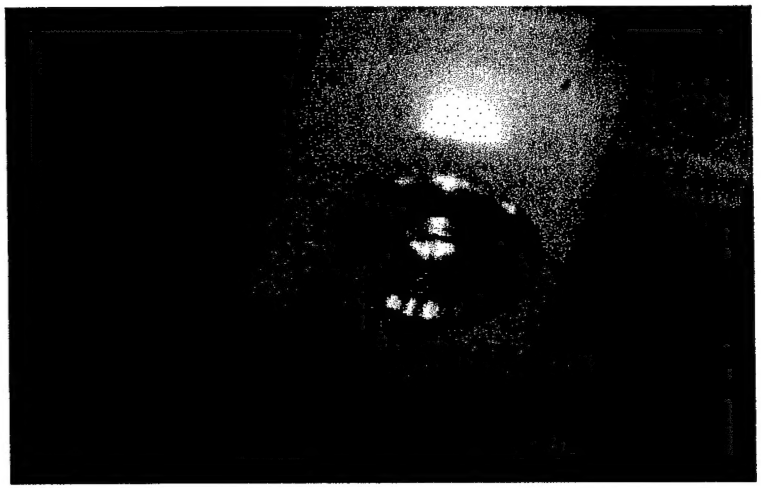


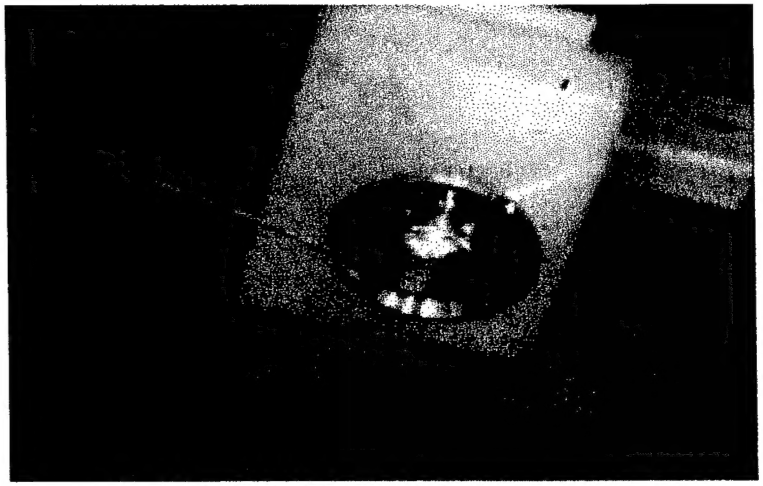
Introduction

- A major requirement for using a solar propulsion system is the the proper placement of the focal spot on the thruster absorber plane. Without proper placement of the focal spot, solar energy is not transferred to the propellant gas or at worst case, a significantly smaller proportion of the incident energy is transferred to the gas.
- Previous work has determined that alignment accuracy is needed to be 0.1 degree for angular and 0.1 inch for translation.
- Human-in-the-loop fine focus image processing handled the focal spot positioning.
- Human-in-the-loop sensor and algorithm needs to be replaced with space flight oriented solution.

Problem

Determine location of solar focal spot on a visually complex thruster absorber and secondary concentrator. Visual complexity compounded by specular reflection from the secondary concentrator.



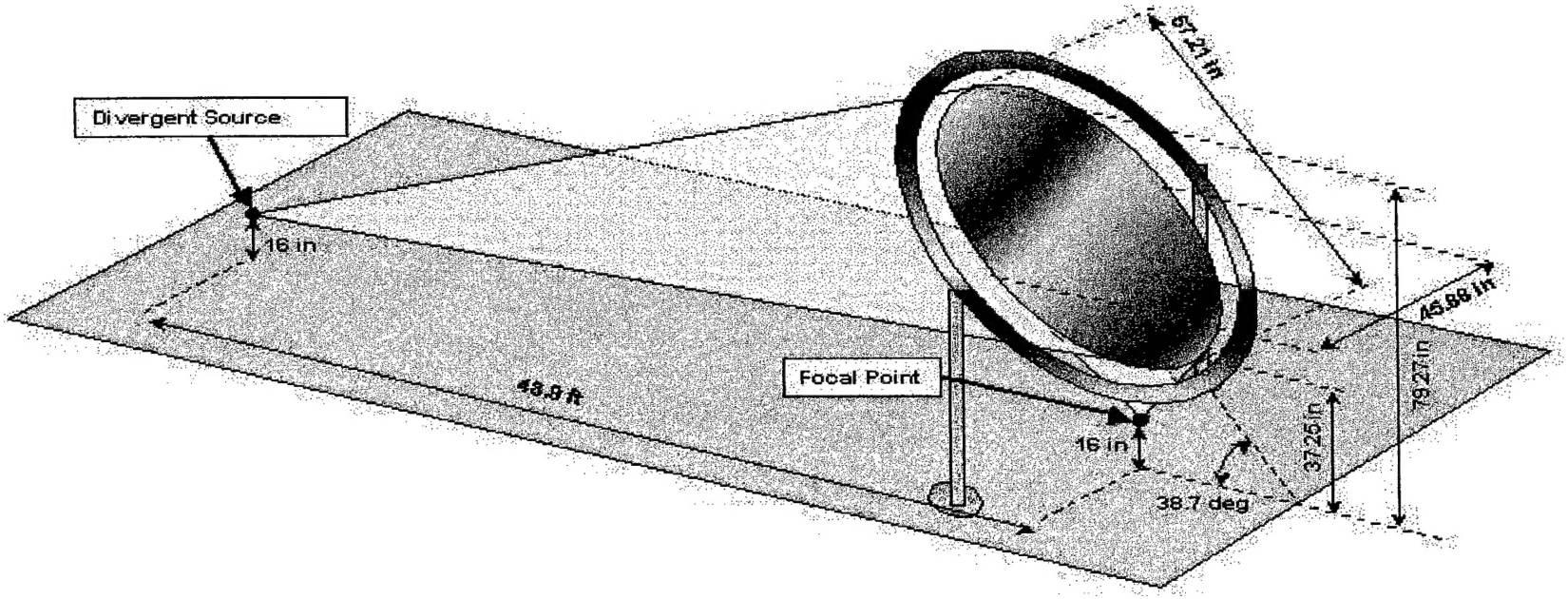


Problem(cont.)

- Fine focus control sensors for positioning of the concentrators have not been defined.
- Method of determining focal spot location within a specular complex image has not been developed.
- Method has not been developed for converting focal point location information into control commands for the primary concentrator.
- Error sources and flexible modes of the concentrator have not been included or completely specified in the concentrator model.

Experimental Setup

Test Apparatus



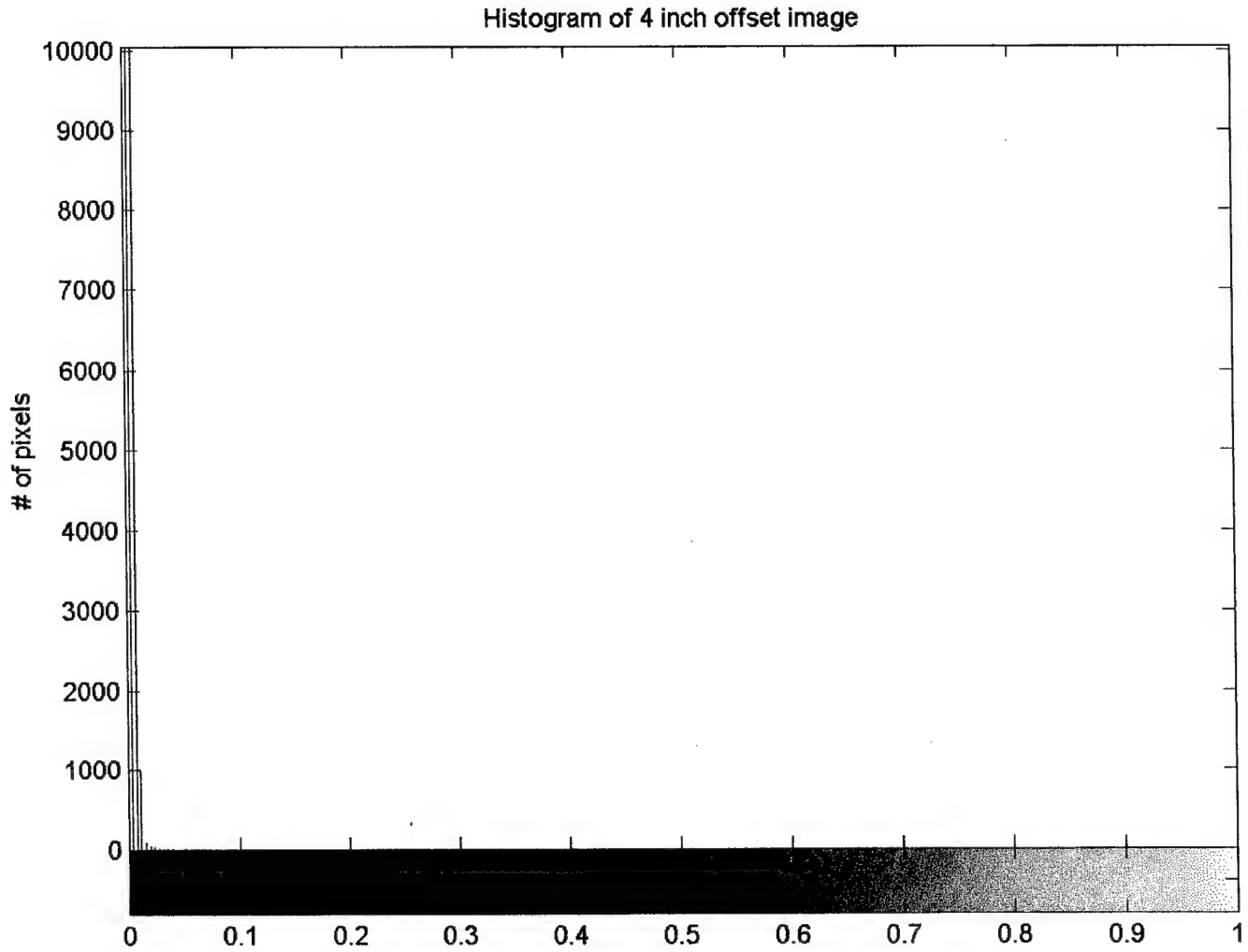
Experiment Description (cont.)

- Charge Coupled Device (CCD) camera chosen as fine focus device for this research.
- SRS 1 X 2 meter elliptical concentrator used to form images on the thruster.
- Divergent light source used to provide simulated sunlight.
- SBIG ST-6 CCD camera used to obtain images.
- Scissors jack on block used to vary positions of the light source.
- Thruster images taken at 1 inch intervals in both vertical and horizontal locations using the 1m X 2m concentrator and a simulated sun light source
- Sony Vaio notebook computer used to take images.
- Matlab used for image enhancement and analysis.

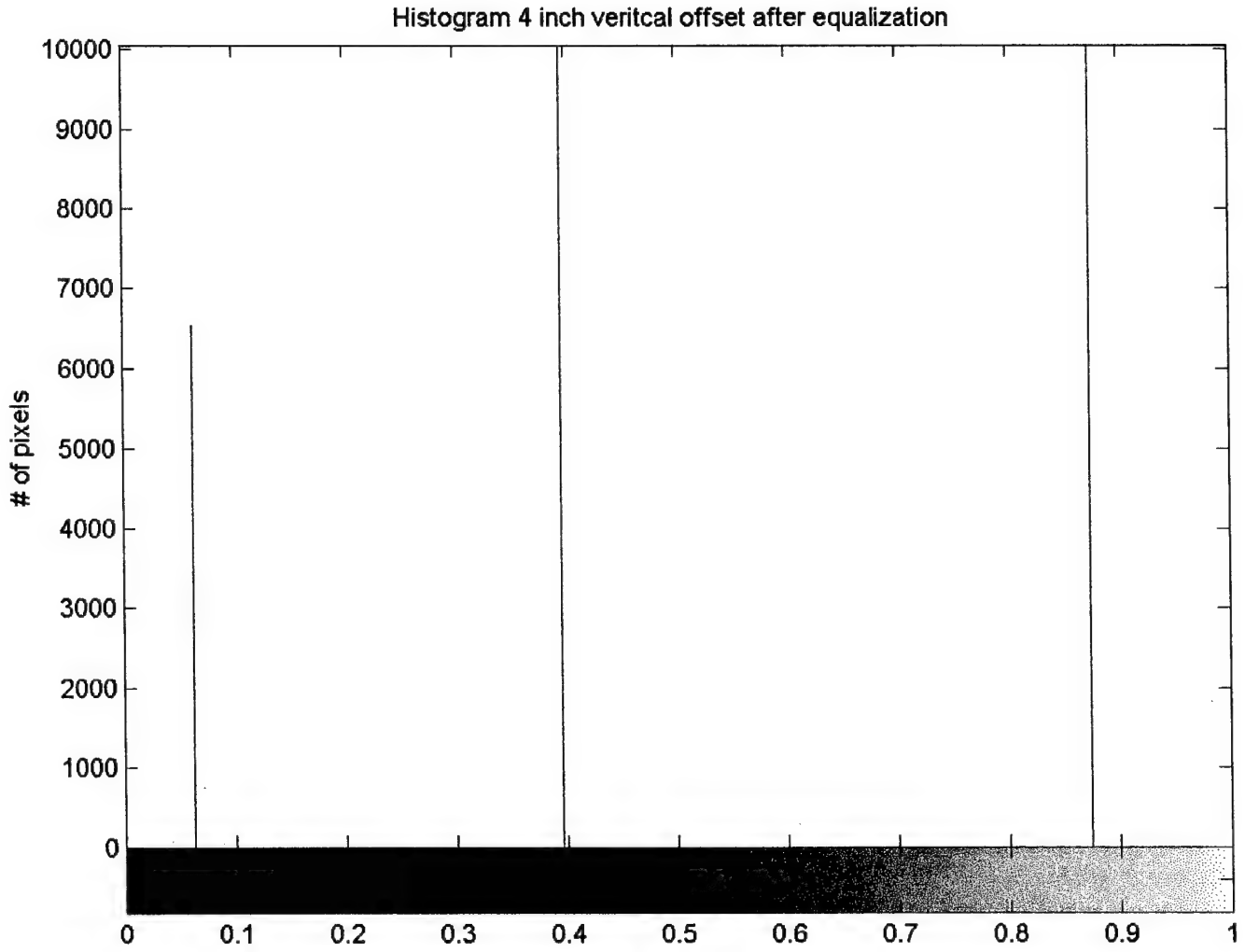
Results and Conclusions

- Histogram equalization of the images was necessary before final processing.
- Averaging filtering was the most useful filtering for using the STFT for determining focal spot location.
- Laplacian and Gaussian filtering was not useful for STFT, but may be useful for locating specular reflections using other methods.
- Images should be taken using a variety of exposures to ensure that the image histograms are more reasonably populated.

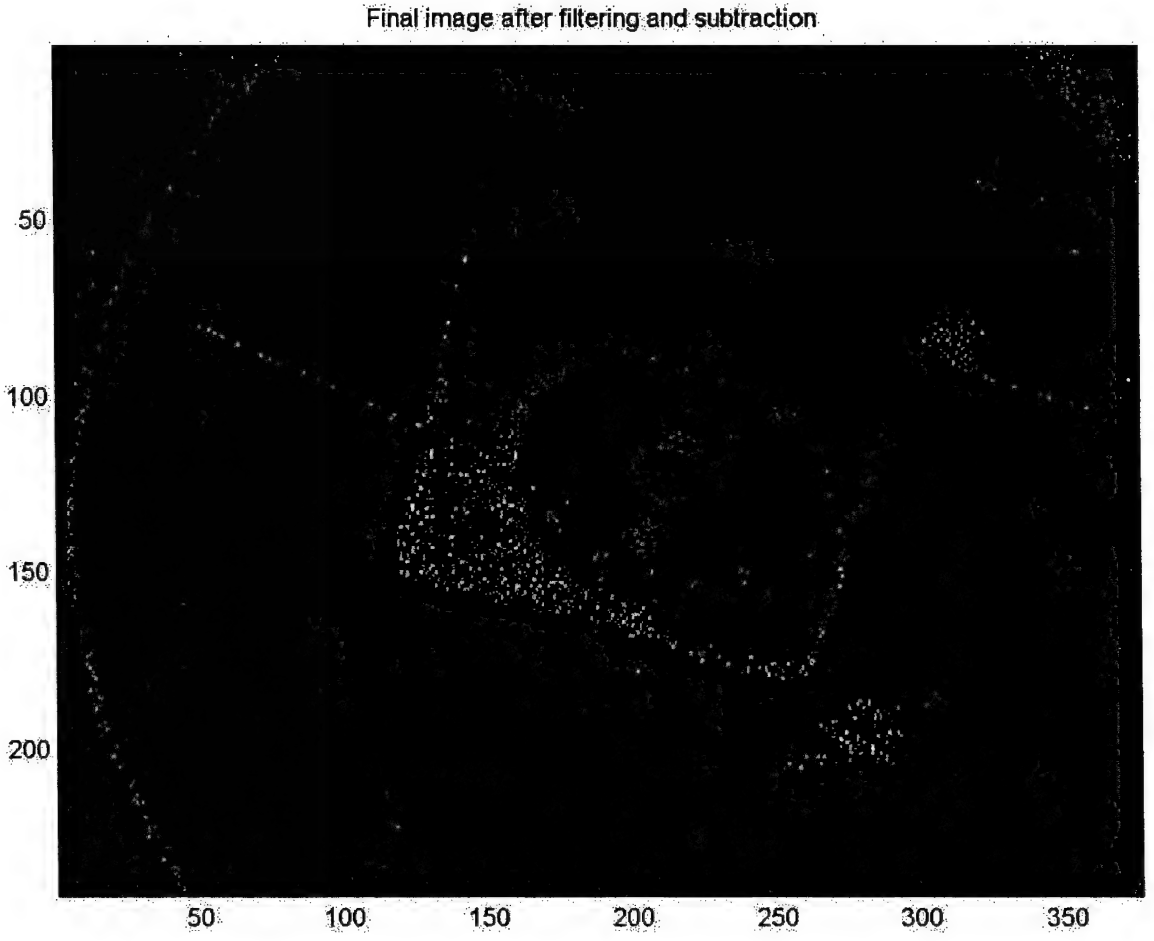
Histogram of Image



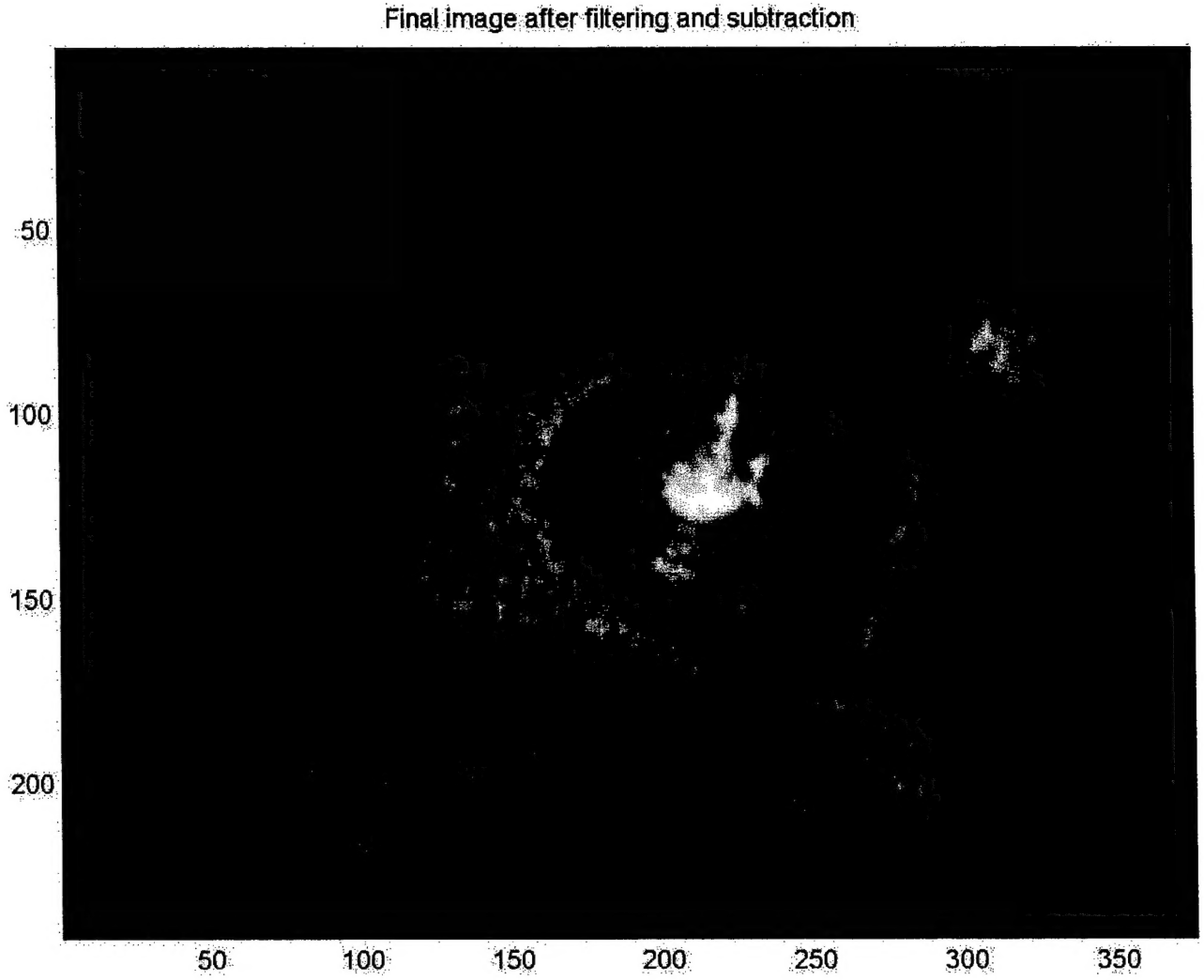
Histogram After Equalization



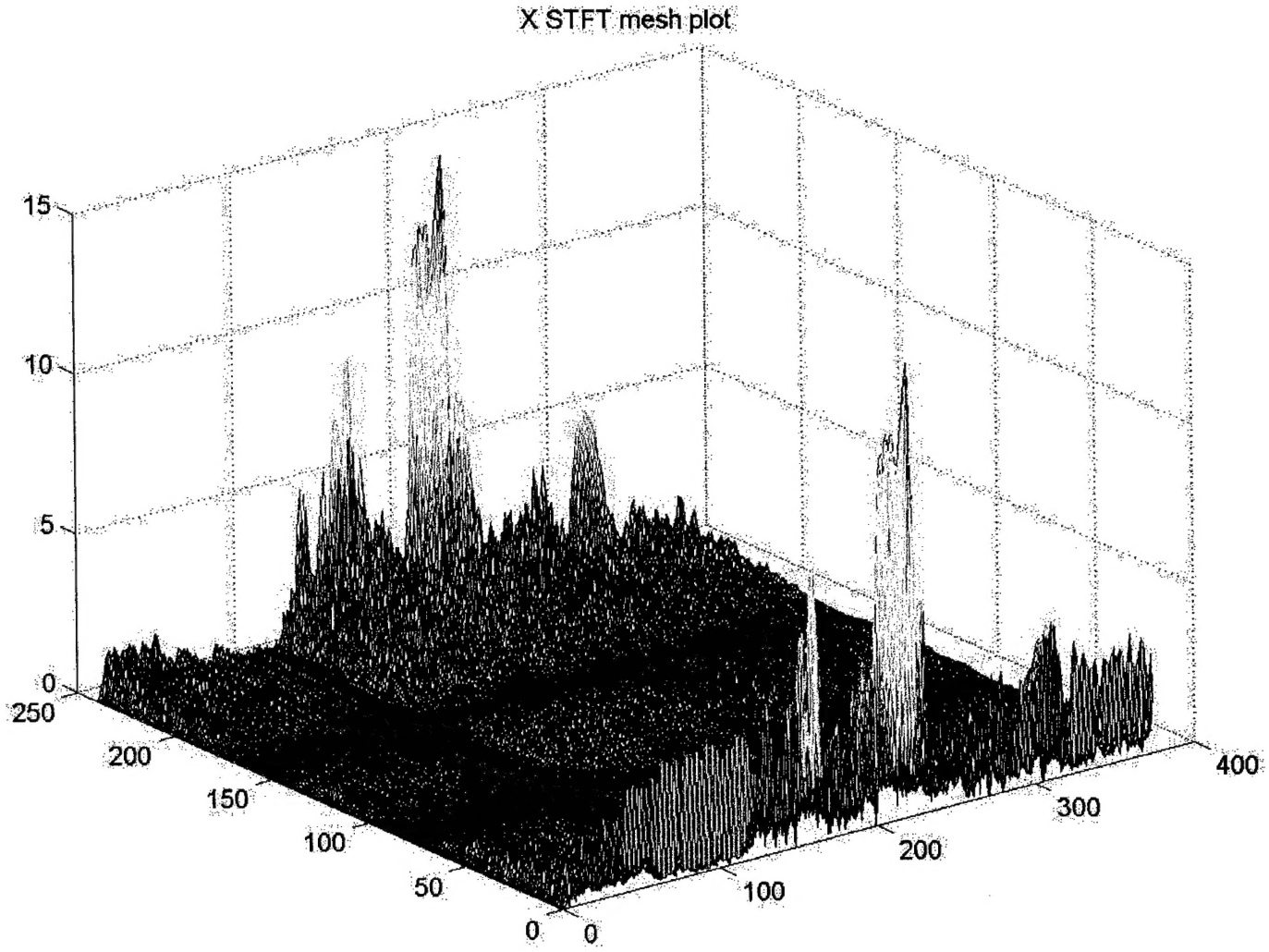
LoG Final Image for Analysis



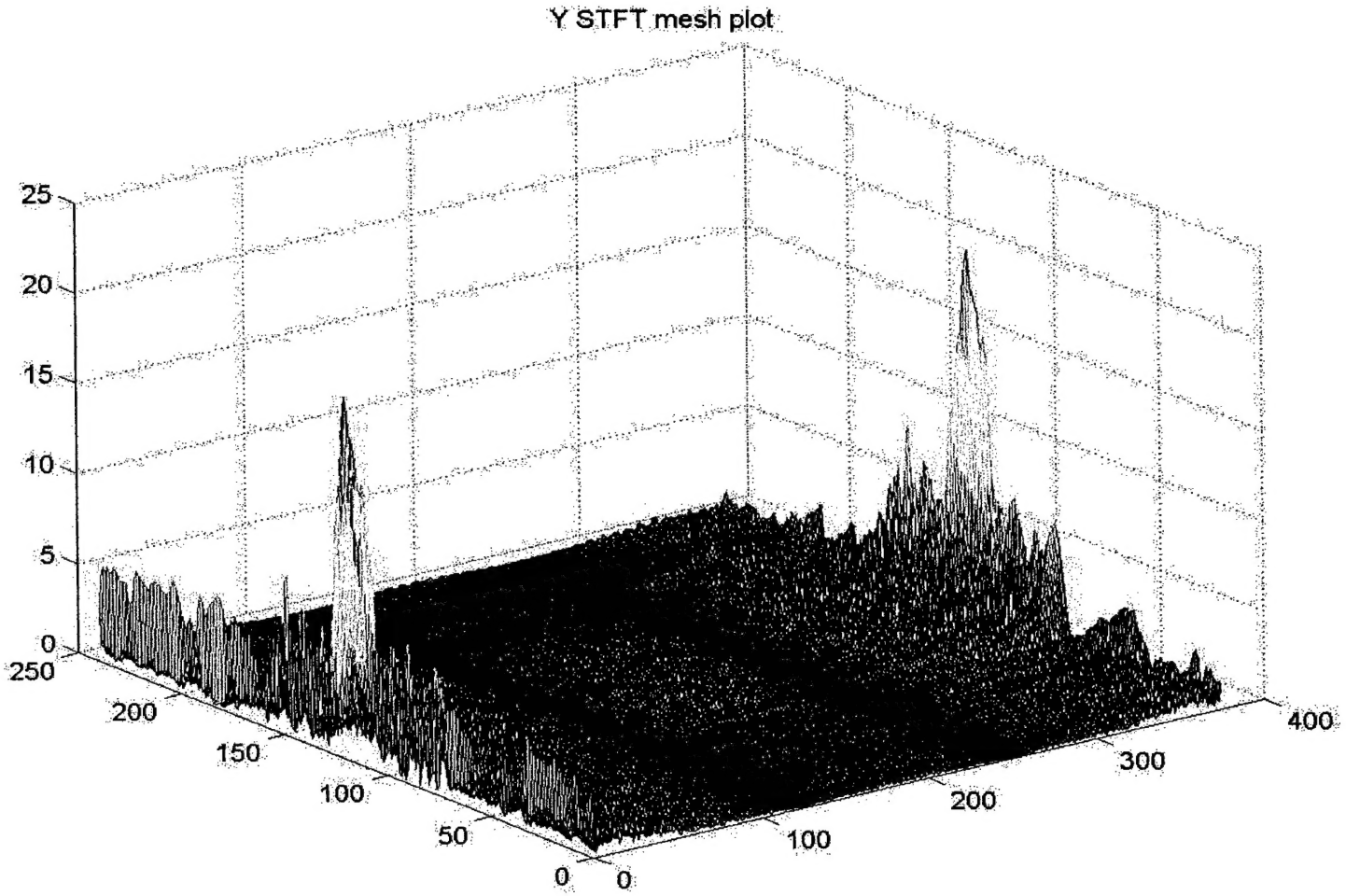
Average Final Image for Analysis



Thruster Image X STFT



Thruster Image Y STFT



Future

- Work on separating specular reflections from diffuse reflections in order to accurately locate and track focal spot. This work would be above and beyond the frequency based work done up to this point. Could be frequency or spatially based or both.
- Work on developing a specular model for the reflectance function of the absorber/secondary concentrator, for use in determining specular-diffuse separation requirements.
- Work on algorithm to convert focal spot location errors to primary concentrator control commands.
- Work on real time hardware requirements for the control system.